a considerable falling of the barometer, that the meteorological station of Ishigakishima reported at noon a barometric reading as low as 703 mm. (27.677 inches). All the telegraphic communications of Formosa were cut off, and it is believed that much damage was done by the typhoon throughout the island.

Another well-developed and severe typhoon swept the Pacific between the Ladrone Islands and the Loochoos from September 22 until the end of the month. Its center was clearly situated west of Guam on the afternoon of September 22, and passed north of the S. S. *Newport News* on her way from Manila to Guam, a gale being reported by her from the southwest to the southeast quadrants and a moderate falling of the barometer. The track of this typhoon is typical of those which recurve north and northeast far from the Philippines and move toward Japan, where the storm is supposed to be raging at the time these lines are being written (Sept. 30).

CLIMATOLOGICAL FACTORS GOVERNING THE SELECTION OF AIR ROUTES AND FLYING FIELDS.

By C. LE ROY MEISINGER.

[Weather Bureau, Washington, D. C., Oct. 4, 1920.]

SYNOPSIS.

Although the current values of weather conditions usually differ radically from the averages, they are important nevertheless in the selection of aerial routes and flying fields. For the preliminary selection of aerial routes, the normal values of the following elements are the most important:

1. Speed and direction of the wind.
2. Frequency of low clouds and fog.
3. Frequency and intensity of thunderstorms.
4. Vertical temperature distribution and its diurnal changes.

For the selection of flying fields there are needed, in addition to the above values, the normal values of precipitation.

INTRODUCTION.

There is, it seems, a vagueness in the opinions of many people regarding the value of meteorology in the selection of air routes. One reads of "pathfinding" and of "charting" flights by which it is implied that a single journey or, at most, several journeys over a proposed course will afford sufficient data to designate that route as satisfactory or unsatisfactory for continued use. Such reasoning is unsound. It is obvious that the aerial medium is possessed of such a host of variable attributes, that the conditions which one finds to-day may not occur again in precisely the same combination for months or even years. Of what profit shall it be to measure the temperature, humidity, and other elements, in a single flight, unless it be that these data are to be used in the discussion of the flight itself, relative to the performance of the motor or instrumental equipment, the physiological reaction of the travelers, or in one or more of the several other problems that may take the form of special tests? If such observations are to be made, they should be made over a wide area, by numerous craft, and as nearly simultaneously as possible. The ocean of air is far from being a fixed thing. Perhaps the likening of the atmosphere to the aqueous ocean is a figure of speech which has been somewhat overdone, and has resulted in the popular conception of aerial currents as fixed as the Gulf Stream or the Japan Current. It is also possible that the pioneer work of Rotch and Palmer, *Charts of the Atmosphere for Aeronauts and Aviators*, which appeared in 1911, did not lay sufficient emphasis upon the pitfalls of too great reliance in averages. Our atmosphere is not made up of great permanent streams and currents, and even our conception of prevailing westerly winds aloft is sometimes shocked by the spectacle of cirrus clouds moving from the north, east, or south. Therefore, efforts to lay down definite airways without reference to the fundamental conditions which really determine desirable routes can not prevent themselves being relegated to positions of slight importance. It would be unfair to assert that any carefully made scientific observation is of no value; but it is obvious that, in such matters as the selection of air routes, other factors than such observations must be considered before one can legitimately make generalizations upon so subtle a medium as the atmosphere.

THE SELECTION OF ROUTES.

It is self-evident that the point of departure and the destination must determine the general direction of flight. But it is by no means axiomatic that the air route shall follow a straight line between these two points. Irregularities of the terrain, its physical characteristics, and the weather along the route must, in the last analysis, determine the course of the aviator, if he is to cover the distance with the greatest economy of time and fuel. In brief, it is the geography and the climate of the region between two stations which must determine the approximate route, but the weather at the time of flight must determine the details of the aviator's course.[1]

While the fact is recognized that a single condition may not be representative of the weather over a given route, and also that mean conditions over the same route may differ greatly from the conditions of any particular day, it is believed, nevertheless, that the best basis for laying out a preliminary route between two points lies in the mean values of certain climatological and aerological factors.

Wind.—Perhaps the most important of all the weather elements to the aviator is the wind. It is necessary in commercial aviation to take advantage of any conditions which will aid in economy of time or fuel or will be conducive to greater safety. If, then, the "pathfinder" is to live up to his name, his first concern must be to determine the speed and direction of the prevailing winds over the proposed route. These winds should be determined, not at the surface alone, but to as great altitudes in the free-air as possible. Moreover, it is very likely that he will discover that certain elevations will, in the long run, be more favorable for flying in one direction, and that other levels will be more favorable for the return journey. Rouch and Gain[2] have shown how important such wind studies are in regard to flying in northern Africa. The journey from Oran to Tunis, they find, should be made at an altitude of about 2,000 meters, because at this elevation a strong westerly wind prevails. The return journey, in the long run, will be made most profitably at an altitude less than half as great, because the westerly wind at that elevation is greatly diminished in force. Such prevailing winds should be determined from as long records as are available and should be worked out for small time units; seasonal

[1] A later article will show how current conditions may modify an air route with a saving in time and fuel.

[2] Les cartes des vents à l'usage des aéronautes. *Revue générale des Sciences*, Mar. 30, 1919, pp. 168-171.

averages would be valuable, but monthly means would undoubtedly be better. Not less valuable in this connection are the means of diurnal wind changes, both in speed and direction. In fact, each additional factor brings the conditions nearer to those which the aviator is likely to encounter in flight.

Digressions from the great circle[3] path between two points would be most helpful in cases of high winds and relatively slow-moving craft. Thus, a high-powered airplane flying at 110 miles per hour in a gentle wind would gain little, if any, by departing from the great circle. But a dirigible, on the other hand, moving at 60 miles per hour might find it very much to its advantage to follow the general direction of wind flow if the wind speeds were quite high and if the curvature of the wind path were such as eventually to bring it near its destination.. Thus, the gain to be made by departing from the great circle becomes smaller and smaller as the ratio of craft speed to wind speed becomes greater.

Cloudiness and fog.—The influence of the lower clouds and fog upon flying is very great. As a rule, it is essential to retain sight of the earth. When there are low clouds and fog, however, to keep in sight of the earth is obviously a hazardous proposition. The disadvantages of low flying when there is a cloud layer quite close to the ground have been set forth by Prof. B. Melville Jones,[4] as follows: 1. Strain to the pilot, owing to constant bumpiness, poor visibility, and proximity to the earth. 2. Danger of collision, occasioned by poor horizontal visibility. 3. Discomfort to pilot and passengers, since flying above clouds is exhilarating. 4. Choice of altitudes is limited, and therefore it is difficult to select advantageous flying levels. 5. Annoyance to people on the ground. 6. Danger in case of forced landings.

While Prof. Jones inclines to the view that overcloud flying has advantages over undercloud flying when the clouds are low, he does not hesitate to point out the danger and discomfort occasioned by having to ascend to great heights to clear clouds; moreover, it not infrequently happens that the cloud layer is thick, or that there are several layers. The danger of flying in clouds is great, not only because of the possibility of loss of sense of balance by the pilot, but because the clouds may reach the ground without his knowledge, thus making a crash likely when attempting to land or descend to lower levels.[5] There is also the danger of being unable to find the landing field at the end of the flight and the difficulty of navigating without visible points on the earth. Whatever may be the advantages of overcloud flying, there is no escaping the fact that low clouds are a menace to the airman.

It is therefore necessary in the laying out of proposed aerial routes to consider carefully the frequency of low clouds and fog. Bodies of water, such as lakes, rivers, and the ocean, as well as cities and deserts, often contribute to the formation of fog and the production of low visibility.

Thunderstorms.—To the pilot of heavier-than-air craft no less than to the pilot of lighter-than-air craft, the thunderstorm is a formidable enemy and one to be studiously avoided. The few who have ever penetrated the interior of a thundercloud have suffered experiences which they would not care to repeat, if, indeed, they have come through alive. Dr. Charles F. Brooks has discussed several instances in which aviators have described their experiences in or near thunderstorms.[6]

Lighter-than-air craft are forced into the uncomfortable situation of having to land, or attempt to fly above, or around, the thundercloud, any or all of which may be extremely difficult. In the case of a dirigible balloon, it may be possible to fly around the storm as an airplane might do, and thus succeed in avoiding it. The alternative of landing in the face of the oncoming storm with its squall wind is not desirable because of the difficulty of handling the balloon on the ground. To attempt to fly over a towering thunderstorm may be entirely out of the question owing to the excessive altitude which would have to be attained, for great altitude necessitates unpleasant physiological effects and the loss of gas (through expansion) and ballast.

It is true that usually the thunderstorm is essentially a local phenomenon, which may attend the passage of the windshift line in a LOW or may be formed locally by strong convection. Thus, the chances of encountering thunderstorms during a given trip are very much dependent upon current general conditions. But the frequency of occurrence of thunderstorms along a given route is a thing that it is vitally important to know. For one may discover that in certain months in a given region the thunderstorm frequency is so great as really to endanger the maintenance of schedules. An aircraft corporation may discover by such statistics that their craft will be placed in great danger by maintaining routes through regions of great thunderstorm frequency. The wisest course in those cases might be to modify the schedule during those times, to select new routes, or to discontinue service in that region temporarily. Again, this knowledge can give some clue to the possibility of profitably modifying the administrative activities of the corporation, such as shifting the personnel of flying fields, distributing equipment, extra parts and supplies. All of these factors will have their reflection in direct financial returns. A blind indifference to the statistics of climate over air routes is, therefore, a narrow business policy, and that corporation which manifests this indifference is the one which, no matter how skilled its pilots, will find its dividends dwindling because of loss of equipment through accidents and consequent loss of popularity with the public.

Temperature.—The knowledge of mean temperatures over routes is perhaps the least important of the weather factors. It is true that temperature has a profound influence upon the maintenance of schedules in extreme weather. But with the improvement of aircraft engines so that they function at extremely low temperatures, and with the electrical heating of the cabins of passenger-carrying planes and dirigibles, the influence of the temperature factor is appreciably lessened. Information regarding average vertical distribution of temperature and of the diurnal change of this distribution is helpful. Unfortunately such data are somewhat limited, but the Aerological Division of the Weather

[3] It is so customary to think of the earth's surface as it appears on a flat map that the fact often is lost sight of that the shortest distance between two points on a spherical surface is the arc of the great circle upon which the two points are located. This applies chiefly to long distances and is used by mariners; but it also applies in the case of long aerial routes.

[4] Flying over clouds in relation to commercial aeronautics, *Aeronautical Journal*, May, 1920, pp. 220-249. Abstract in *Aeronautics*, Mar. 18, 1920, pp. 240-243; also in this REVIEW, pp. 528-529.

[5] The writer had such an experience in a free balloon. Having ascended into a rather low layer of clouds and having lost all sense of direction, the party was surprised to discover several hours later that the trail rope of the balloon was dragging on the ground. The low clouds had actually reached the surface. For full account, see "A free balloon flight in the northeast quadrant of an intense cyclone," MONTHLY WEATHER REVIEW, April, 1919. 47: 233-235.

[6] The effect of wind and other weather conditions on the flight of airplanes. MONTHLY WEATHER REVIEW, August, 1919, pp. 523-532. See also Meisinger, C. LeRoy: A balloon race from Fort Omaha through thunderstorms, idem., pp. 533-534.

Bureau is conducting a study of a great number of kite flights which will probably supply to a large degree this need. The knowledge of mean vertical temperature distribution is not as important in the preliminary laying out of air routes as in the discussion of the current data supplied to the aviator just before he ascends.

Humidity and precipitation.—These elements are not of great importance at the outset, and they are so interwoven that their value depends chiefly upon the interpretative ability of the consulting meteorologist at the flying field.

THE SELECTION OF FLYING FIELDS.

The problem confronting the person whose duty it is to select a flying field is not an easy one; or, at least, it is one that can not be rightly solved by a mere consideration of the civil or military requirements. To-day, with the multitude of flying routes being established, it sooner or later becomes the problem of the commercial clubs or chambers of commerce in most large cities to determine a landing field in the immediate vicinity. These fields have a great commercial value to the city. It is not denied that many of the local aspects, such as the availability of property, accessibility, etc., each peculiar to a given locality, rightfully have a foremost place in the consideration. But the meteorological aspect can not be neglected, for it is conceivable that, in spite of a hundred desirable features of a landing field, there may be certain characteristics which, from a meteorological standpoint, will render it utterly unfit for the purpose. Again assuming the climatic features to be favorable, the field itself must be so laid out that it will serve most efficiently. That is to say, for instance, that the long axis of the field, if it be small and rectangular as many are, should lie in the direction of the prevailing wind at the place, because it is necessary that planes land heading into the wind and that they also rise in a headwind. The buildings should be so oriented and distributed as to interfere the least with landing or rising planes, and where the eddies and gusts they cause will not interfere with craft flying low over the field.

A very striking example of the consequences of neglecting the meteorological aspects is given by Rouch.[7] During the war, the British desired to establish a training field for aviators for bombing instruction, and a commission was appointed for the purpose of determining the location. The shore of Loch Doon, in Ayrshire, was chosen. After the work of establishing the field was well along, the hangars were being built, a railroad was contracted for, and other expensive arrangements had been made, it was discovered that the neighboring hills gave rise to eddies and squalls which absolutely prevented safe flying at that place. The field was abandoned with a loss to the Government of upwards of $2,000,000. In conclusion, Rouch says, "The installation of some instruments and the consultation of some tables of figures would have permitted 12 million francs to be saved. In that circumstance, sadly writes the *Times* (London), the authorities did not perform their duty." It is unnecessary to emphasize the import of this example.

The Air Service recognizes the tremendous importance of the climatological considerations in the selection of flying fields.[8] To quote from the circular which discusses this question:

> The number of flying days to be expected in a year or in any month may be fairly well determined from a study of the climatic factors. * * * It is also possible from this study to arrive at a fairly definite conclusion as to the accessibility of the field by aerial routes for different types of aircraft. In other words, one may determine the sort of aerial harbor, ease of entrance, exit, and other things considered which aircraft would find at a given field. * * * The prevailing wind and storm directions largely determine the layout of a field. The number of days to be expected when the wind speed is too high for the operation of aircraft may be closely determined. Also the number of days with excessive precipitation, with fog or storm to be expected, may be closely approximated.

The weather factors to be taken into consideration are quite the same as those which may determine aerial routes. Precipitation comes in for greater consideration in the case of landing fields. A plane can not land or take-off readily on a muddy field, and a snow cover demands the greatest attention.[9] As the Air Service circular points out, topography and wind are inseparably bound together in relation to aeronautics. The effect of wind blowing over a rough terrain is to produce rough air in which to fly. Landing fields in a hilly region are especially apt to be dangerous; and the proximity of trees and high buildings is likely to cause roughness extending to a height three or four times as great as the object. This is dangerous to a plane slowing down for a landing or for slow-flying planes.

CONCLUSION.

An effort has been made to present the vital importance of meteorological studies in connection with the establishment of aerial routes and the layout of flying fields. The argument does not pretend to overstress the use of averages in connection with such work, but it does attempt to emphasize their importance in the preliminary work. Meteorology is the mainstay of aviation regardless of the confidence of the aviator in his motor and its ability to carry him safely over all obstacles. The dirigible has inspired us with a confidence in its future as a commercial transport; the aerial mail has definitely stamped the airplane as a reliable means of rapid transportation of mail, baggage, and passengers. Great aerial corporations are being organized. They are commercial enterprises, highly capitalized, and founded for the purpose of paying dividends to their stockholders. Dividends depend upon the skillful management of the assets of the company, the reduction of the expense of maintenance, the extension of routes into the most profitable places, the acquisition of the public confidence. Every accident is detrimental to the cause of aviation, not alone because of the direct financial loss, but because it weakens the public confidence. The record of the Aerial Mail Service shows that the weather is responsible for the greatest number of accidents and forced landings.[10] Many of these could be avoided by giving the weather its due consideration. Here is one of the places where the consulting meteorologist is urgently needed.

[7] Préparation météorologique des voyages aériens. Paris, 1920, pp. 53–54.

[8] Meteorology and Aeronautics. *Air Service Information Circular*, May 12, 1920, vol. 1, No. 77.

[9] A note in *Aeronautics*, Mar. 18, 1920, p. 230, tells of the addition of ski attachments to the plane where landings have to be made on snow. One of the great difficulties of landing on snow, as on water, is to tell how high the airplane is above the surface, for, with a perfectly smooth snow cover, it is difficult to judge distance; and even to know when the skis are actually in contact with the snow.

[10] Effect of weather on the Aerial Mail Service. MONTHLY WEATHER REVIEW, June, 1920, pp. 335–336.

METEOROLOGY AND AERONAUTICS.

The *"Air Service Information Circular (Heavier-than-air)"* published by the Director of the Air Service at Washington, under date of May 12, 1920, contains an interesting statement of the kind of meteorological information that is required in the location, layout and maintainance of heavier-than-air flying fields. The meteorologist who is not in personal touch with the practical problems confronting the aviator is prone to neglect or to fail to recognize certain climatological or meteorological aspects of the aviator's work.

The circular is evidently intended to be of service to the aviator or engineer confronted with the task of selecting landing fields, or to the army meteorologist whose duty it is to supply the current meteorological data after the field is in operation. The methods employed by the Meteorological Section of the Signal Corps in France are presented, together with some of the charts which were found useful during the war, namely, the light chart, showing daylight, twilight, moonlight, and starlight, and the chart of magnetic declination. At the end is a short bibliography on aerology and meterology.

As a guide to these men in the service whose work falls along this line, this circular may serve a useful purpose. But to the meteorologist this concise statement from the flyer as to what he wishes to know about meteorology should serve as a timely guide as to the direction along which he should proceed. In France, J. Rouch has prepared a booklet entitled *"Préparation Météorologique des Voyages Aeriens."* There is a field for a similar but more comprehensive work in the United States.—*C. L. M.*

FLYING OVER CLOUDS IN RELATION TO COMMERCIAL AERONAUTICS.[1]

By Prof. B. MELVILLE JONES.

[Abstract and excerpts from a brief of this paper in *Aeronautics*, Mar. 18, 1920, pp 240-243.]

The problems confronting the aviator on a long distance flight, when there is a heavy cloud layer quite close to the ground, are manifold. The author inclines toward the view that flying above the clouds has many advantages over flying below clouds, and this view was also held to a greater or less degree by those who participated in the discussion. The difficulties of undercloud flying as enumerated by the author are:

"1. Strain to pilot. [Poor visibility, bumpiness, proximity to earth.]

"2. Danger of collision. [A growing problem, accentuated by poor horizontal visibility.]

"3. Discomfort to passengers and pilots. [Flying above clouds exhilarating; below is depressing.]

"4. Loss of power to use favorable winds. [Choice of altitudes limited.]

"5. Annoyance to people on ground. [As routes become definitely established the noise of high-powered engines would be annoying.]

"6. Danger in forced landings." [One may have a better idea of the nature of the land when flying low, but this would be offset by two advantages from flying above clouds, namely, time to remedy slight mechanical troubles in the air without completing the landing, and, if the pilot were familiar with surface wind direction, opportunity to turn aeroplane so as to land against the wind.]

The difficulties of flying above clouds are also enumerated:

"1. Difficulty of actual in-cloud flying. [Loss of sense of balance by pilot is now being overcome by new instruments.]

"2. Danger that the clouds might come to the ground whilst the aeroplane was in or above them.

"3. Difficulty of navigation. [Must be carried out by dead reckoning, astronomical observation, observation of kite balloons or other guide marks, or wireless.]

"4. Difficulty of finding aerodrome at end of flight.

"5. Danger of collision in clouds.

"6. Possibility of having to reach great heights to clear clouds. [Uncomfortable temperatures and physiological effects.]

"7. Danger from storm clouds."

While this paper discussed the entire problem from the standpoint of commercial aeronautics, and the mobilization of resources and organization to assist in commercial aviation, it is important to note that the paper was occasioned purely by meteorological phenomena. Also, of the 13 dangers enumerated under the heads of undercloud and overcloud flying, seven are directly the result of meteorological conditions, while the remaining five are physiological and mechanical. This emphasizes the fact that the aviator is more dependent upon his understanding of meteorological phenomena than upon all other factors combined, if he will fly with the greatest safety and comfort.

The paper was followed by a discussion[2] in which some of the foremost British aviation authorities participated. Among other points brought out by these men there were several regarding the meteorological organization which will permit of greater safety in flying. One of the points of discussion was how to have a continuous record of wind speed above the clouds. Maj. Dobson said that an instrument for use on a kite balloon had been developed which might give some assistance in this direction, and that a modification of it was desirable which would permit of the recording devices registering at the ground continuously. This would do away with the necessity of hauling the balloon down.

Mr. J. R. Pannell brought out an important point concerning the use of altimeters on long flights. While the pilot is in the air, the barometric pressure may change, with the consequence that his altimeter reading, which was last set before he ascended, might be as much as 300 feet in error. If he is traveling over land whose elevation is variable, his altimeter does not indicate height above the surface, but height above the starting point. To correct this difficulty, changes of surface barometric pressure should be given to the plane by wireless, thus allowing the aviator to make the necessary correction. If there were a means of independently knowing the height, a record of barometric change could be made on the craft. This would be of great advantage to a dirigible on a cruise of several days.

The author summarizes the discussion as follows:

"1. That the power to fly in safety over clouds would be of great value to the commercial value of aviation.

"2. That routine flying over clouds can not be undertaken safely with the facilities at present available to the commercial world.

"3. That probably it could be made safe with a suitable organization of ground stations and meteorology and provided that reliable instruments were more generally available * * *."

[1] Paper read before the Royal Aeronautical Society, March 3, 1920; published in full in Aeronautical Journal, May, 1920, pp. 220-249.

[2] Published in *Aero. Journ.*, loc. cit., pp. 238-247.